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A GEOMORPHOSITES SELECTION METHOD FOR EDUCATIONAL PURPOSES: A CASE STUDY IN TREBBIA VALLEY (EMILIA ROMAGNA, ITALY)

ABSTRACT: BOLLATI I., PELFINI M. & PELLEGRINI L., *A geomorphosites selection method for educational purposes: a case study in Trebbia Valley (Emilia Romagna, Italy)*. (IT ISSN 0391-9838, 2012).

In the Earth Sciences, geoheritage evaluation is becoming increasingly important. The dissemination to the general public of knowledge of landforms and the related genetic and evolutionary processes that characterize the Earth's surface may be considered a useful tool because these processes, that concur to the modification of the landscape, interact directly with human elements in the landscape and may be influenced by human activity too. The efficacy of methodologies for evaluation and selection of sites of geomorphologic interest (geomorphosites) remains of fundamental importance in order to correctly individuate the most meaningful natural spots that represent the stages of geological/geomorphological evolution of an area to be presented to an audience. For this reason, the structuring of a relational database for storing and managing data related to geomorphosites, specifically for educational purposes, is herein proposed. The efficacy of popularization of the geomorphosites depends on the selection of the most suitable geomorphosites. The results of a comparison of 13 sites along the Trebbia River (Emilia Romagna, Italy) are presented in order to highlight the differences that can emerge among these sites using the database. On the basis of these results, some sites along the Trebbia Valley have been selected to create an educational itinerary, including fieldwork, to be proposed to a first level of secondary school.

KEY WORDS: Geoheritage, Geomorphosites, Relational database, Educational applications, Trebbia Valley (Emilia Romagna, Italy).

RIASSUNTO: BOLLATI I., PELFINI M. & PELLEGRINI L., *Metodologia di selezione dei geomorfositi a scopo didattico: un caso di studio nella Val Trebbia (Emilia Romagna, Italia)*. (IT ISSN 0391-9838, 2012).

Nell'ambito delle Scienze della Terra la valutazione del patrimonio geologico-geomorfologico sta acquisendo un ruolo di primaria importanza. La divulgazione al grande pubblico delle conoscenze riguardo alle forme del paesaggio e ai relativi processi genetico-evolutivi che caratterizzano la superficie terrestre è uno strumento basilare. Infatti risulta importante far comprendere come i processi geomorfologici che concorrono alla modificazione del paesaggio interagiscano in questo senso anche con gli elementi antropici inseriti nel paesaggio stesso e che allo stesso tempo il modellamento delle forme del terreno non sia dovuto solo a processi naturali ma spesso anche a quelli antropici. Il problema dell'efficacia delle metodologie di valutazione e selezione dei siti di interesse geomorfologico (geomorfositi) rimane un punto di fondamentale importanza al fine di individuare correttamente le evidenze naturali che meglio rappresentino gli stadi dell'evoluzione geologico/geomorfologica di un'area e che possano essere offerti a differenti tipologie di fruitori. Il database che consente di immagazzinare ed elaborare i dati relativi ai geomorfositi, qui proposto con particolare attenzione alle finalità didattiche, è stato progettato per rispondere a queste esigenze. La possibile divulgazione di concetti scientifici attraverso i geomorfositi deriva infatti da una corretta selezione dei siti più adatti e più rappresentativi. Nel presente lavoro vengono riportati i risultati del confronto tra 13 siti individuati lungo il Fiume Trebbia (Emilia-Romagna, Italia) per evidenziare le differenze che emergono tramite l'utilizzo di questo database. Sulla base dei risultati ottenuti alcuni siti valutati in Val Trebbia sono stati selezionati per creare un itinerario didattico, che comprende anche attività di terreno, realizzabile in scuole secondarie di primo grado.

TERMINI CHIAVE: Patrimonio geologico-geomorfologico, Geomorfositi, Database relazionale, Attività didattiche, Val Trebbia (Emilia Romagna, Italia).

INTRODUCTION AND AIMS

The landscape and all the features generated by geomorphological processes represent a part of the natural and cultural heritage of a territory (Panizza & Piacente, 2003). The role of geomorphology in this heritage value has been synthesized in the term geomorphosite (Panizza, 2001), defined by Panizza & Piacente (2003) as: «a landscape or landform that has particular and meaningful geomorphologic attributes which qualify them as a component of the cultural heritage (in a broad sense) of a territory».

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At present geomorphosites are studied in detail for their scientific attributes and for their implications for landscape evaluation, tourism promotion, and education. A huge amount of literature has been produced since the 1990's focusing on different issues relating to geomorphosites (for more detailed references see Reynard & *alii*, 2009 and Bollati & Pelfini, 2010):

– Individuation and census of sites by studying the geological and geomorphological setting of the area. Knowledge of the area represents the base for subsequent issues. Fundamental criteria for the selection of potential geomorphosites are indicated, for example, in Pereira & Pereira (2010);
– Numerical assessment of the values in order to rank the potential geomorphosites on the basis of different parameters and criteria that vary slightly among different authors (Reynard & *alii*, 2009; Bollati & Pelfini, 2010);
– Development of mapping methodologies and divulgation strategies for popularizing geoheritage in order to find the best ways to make the results of the selection enjoyable by the most (e.g. Regolini-Bissig & Reynard, 2010);
– Investigations of risk and impacts deriving from geomorphosite fruition (e.g. Piccazzo & *alii*, 2007; Pellegrini & *alii*, 2010): a topic particularly meaningful in the case of active geomorphosites (*sensu* Reynard, 2004).

These points can be considered as the steps of the procedure for geomorphosite analysis.

One of the most debated topics at the moment is the quantification of geomorphosite value because it may have impacts on the final use of the sites (scientific research, educational applications, valuation and promotion…) (Pralong, 2005; Reynard, 2008) and for this reason, as well as to make the sites as comparable as possible, it should be as objective as possible (Grandgirard, 1999; Bruschi & Cendrero, 2005; Coratza & Giusti, 2003, 2005; Pereira & *alii*, 2008).

In fact, the selection phase is very subjective (Bruschi & Cendrero, 2005) and in order to avoid the problem of subjectivity, the choice of numerical values, corresponding to particular categories for each selection parameter, is fundamental during the evaluation phase. In this paper the application of a relational database, structured for the quantification of attributes of sites of geomorphological interest, is proposed, focusing on the realization of an educational fieldwork. In more detail, the aims of the paper are to:

i) propose a methodology to quantify geomorphosite value, based on a relational database used to uniformly manage data from different morphoclimatic and morphogenetic environments and data from different study areas depending on the evaluation purposes;
ii) apply the database functions to a sample area (Trebbia Valley, Emilia Romagna), adapted to the final aim of the selection. In this specific case, it involves the creation of an educational itinerary that includes fieldwork in which the active geomorphosites (*sensu* Reynard, 2004) may become a useful tool for understanding the physical landscape and its evolution in a fluvial environment.

The database application has been articulated in the following steps: i) selection and definition of criteria for evaluating the sites, based also on existing literature; ii) structuring of a relational database according to the selected criteria, and implementing formulas to rank geomorphosites and itineraries; iii) applying the proposed model in a sample area (Trebbia Valley, Emilia Romagna, Italy) with the aim of creating an educational itinerary for the first level of secondary school, along the Trebbia River.

STRUCTURING A RELATIONAL DATABASE FOR GEOMORPHOSITE EVALUATION

The relational database, that has been elaborated and tested in this research, is structured through forms; from a main form it is possible to access all the steps of the geomorphosite evaluation procedure. The database has been built using a commercial package and adopting the following criteria:

– setting a logical sequence in order to help users in the data storage phase through the use of pre-set forms;
– granting the integrity of the database through the institution of rules: no record duplication is allowed and some information is a mandatory requirement.

The functioning of the database is planned in three main steps (fig. 1):

i. geomorphosite data entry;
ii. geomorphosite/itineraries data elaboration;
iii. geomorphosite/itineraries/groups data reporting.

All these actions are guided through buttons and the user can exploit the most important function of the tool even if he is not a competent user of relational databases.

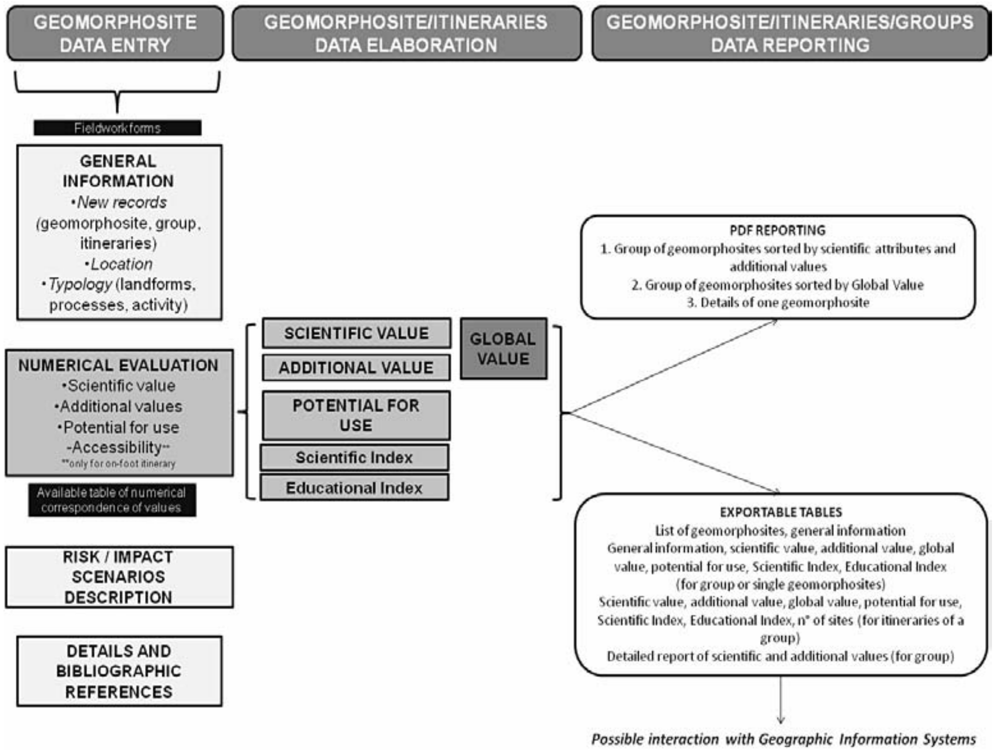
In order to ensure the collection of all the necessary information in the field, a portable document format file of fieldwork forms has been arranged and a link to it has been set on the main form.

For each entry step (table 1) a form has been created to facilitate the data entry, which is carried out almost entirely by combo boxes. In most cases, and in more detail in the case of the numerical parameters, the choices that the operator can make are limited to a pull-down menu.

In the first part it is possible to insert all the general information regarding the site (geographic coordinates, geomorphological description...) and useful data for quantitative assessments of scientific and additional value, as well as the potential for use and risk/impact scenario considerations (table 1 and 2).

The first step in the data entry procedure is the creation of new records/entities that are the object of evaluation: geomorphosite, itinerary, and group. They are linked to each other to proceed to the cross-evaluations and selections. These records are intended to be univocal inside the database; in this sense, the integrity of the database and the uniqueness of the research for reporting and exporting tables are granted, as mentioned before.

FIG. 1 - Sketch of the database structure. The three main sections in which the database is articulated are represented.



In the formula, each parameter has a score between 0 and 1 but the ranges are different in function of the number of alternative choices. From the main form it is possible to access the portable document format file for the table of numerical parameters used for the scientific and additional values, the derived global value, and finally the potential for use.

Once all the scientific and additional features and the potential for use parameters are inserted, it is possible to run the elaborated formulas (all details in table 3) through buttons. The calculation of the potential for use differs depending on whether or not the itinerary is on foot.

Finally, it is possible to export the results as pre-set tables or portable document format file (pdf).

TABLE 1 - Sketch of the information that can be stored in the database

a. NEW RECORDS	b. GEOMORPHOSITES - ITINERARY - GROUP OF GEOMORPHOSITES	
a. GEOGRAPHIC INFORMATION	Localization; Itinerary, Group; Hydrographic basin; Geographic coordinates (X; Y); Altitude; Cartographic references;	
b. GEOMORPHOLOGICAL DESCRIPTION	Landform; Genetic process; Genetic classification; Typology; Complexity; Activity degree	
c. SCIENTIFIC VALUES	see Table 1	
d. ADDITIONAL VALUES	see Table 1	
e. POTENTIAL FOR USE	**(A)** Temporal accessibility (TA); Visibility (Vi); Services (Se); Number of tourists (NT); Sport activities (SA); Legal constraints (LC); Use of geomorphological/geological interest (UGI); Use of the Additional Interests (UAI); Presence Of Geomorphosites In The Surroundings (SGs)	
	(B) SPATIAL ACCESSIBILITY (SAc)	ACCESSIBILITY (CA) Typology (Ti); Trend (Tr); Steepness (St); Sloping (Sl); Width (Wi); Ground Material (GM); Vegetation On The Slope (SV); Water/Snow Along The Path (WSP); Slope Material (SM); Degree Of Conservation Of The Path (DC); Human Interventions (HI); Tourist Information (TI)
f. RISK/IMPACT SCENARIOS	Hazards typologies, threat to geomorphosite survival, hazard degree; Vulnerability: mileage difficulties, environment knowledge, meteorological conditions, vulnerability degree. Level of visual impact, level of impact on scientific value	
g. DEEPENINGS AND DESCRIPTIONS	Descriptions of: scientific value, other geologic interests, additional values, educational suitability and target, accessibility; bibliographic references attachments links	

TABLE 2 - Synthesis of the criteria for the evaluation of the global value of geomorphosites. The main bibliographic references and relative comments are indicated. Abbreviations in brackets are the ones used in the formulas

SCIENTIFIC VALUE (SV)	**Bibliographic reference**	**Comments**
MODEL OF GEOMORPHOLOGICAL EVOLUTION (GM)	Grandgirard (1999); Panizza (2001); Reynard & *alii* (2007); Pereira & *alii* (2008)	
MODEL OF PALAEOGEOMORPHOLOGICAL EVOLUTION (PgM)	Panizza (2001)	Reynard & *alii* (2007) as palaeogeographical value, Earth and climate history. Rodrigues & Fonseca (2010): palaeoenvironmental
EDUCATIONAL EXEMPLARITY (EE)	Panizza (2001); Coratza & Giusti (2005); Pereira & *alii* (2008); Garavaglia & *alii*, 2010	Educational Value outside the Global scientific value for Reynard & *alii* (2007) and among additional ones for Serrano Cañadas & Gonzalez Trueba (2005)
SPATIAL EXTENSION (SE)	Coratza & Giusti (2005)	
GEODIVERSITY (Gd) - *sensu* Eberhard (1997): «…a range of processes (biological, hydrological and atmospheric) currently acting on rocks, landforms and soils»	Gray, 2004; Pereira & *alii* (2008)	
GEO-HISTORICAL IMPORTANCE (GI) - importance for Earth sciences development (scientific publications...)	Coratza & Giusti (2005); Pereira & *alii* (2008)	It is considered as participating to the cultural value by Reynard & *alii* (2007)
ECOLOGIC SUPPORT ROLE (ES) - associated biological features	Panizza (2001); Pelfini & *alii* (2010)	Considered as additional values by Coratza & Giusti (2005), Reynard & *alii* (2007), and Pereira & *alii* (2008); functional value (Gray, 2004)
OTHER GEOLOGICAL INTERESTS (OI) - associated geological features	Pereira & *alii* (2008)	
INTEGRITY (In)	Panizza (2001); Coratza & Giusti (2005); Pereira & *alii* (2008)	Panizza (2001) used this attribute as qualifying of each scientific attribute he individuated. Rodrigues & Fonseca (2010) considered integrity in the vulnerability assessment of sites
RARENESS (Ra) - in regional, national and international contexts	Grandgirard (1999); Panizza (2001); Coratza & Giusti (2005); Reynard & *alii* (2007); Pereira & *alii* (2008)	
ADDITIONAL VALUES (AV)	**Bibliographic reference**	**Comments**
CULTURAL (C) - associated cultural assets, religious and sociologic mores…	Panizza (2001); Panizza & Piacente (2003); Reynard & *alii* (2007); Pereira & *alii* (2008)	
AESTHETIC (Ae)	Panizza (2001); Reynard & *alii* (2007); Pereira & *alii* (2008)	Aesthetic geotopes were defined by Reynard (2004)
SOCIO-ECONOMIC (SE) - relation with tourism-economy	Panizza (2001); Reynard & *alii* (2007)	

One of the tables has been structured to export, through pre-set queries, the calculated scientific value, additional values, global value, potential for use, scientific index and educational index, ordering the sites by global value. The information recorded in the Location section (X, Y coordinates, table 1) and recalled in this table allows the creation of punctual shapefiles after exporting the table, to be elaborated through geographic information systems. In this phase, it is possible to join or relate all the other information exported by all the other arranged tables, linking them through the geomorphosite identifier. This allows spatial analysis to determine the most suitable areas, considering for example the highest global values, the educational index or single attributes (cultural value, etc...). Finally, the crossing with other spatial data coming from outside the database provides an overview of the territory regarding the actual geomorphological setting.

PARAMETERS FOR EVALUATING AND DESCRIBING GEOMORPHOSITES

In recent years there has been an increase in the literature regarding quantitative criteria for evaluating geomorphosites (Bollati & Pelfini, 2010), and the main topics related to geomorphosites have been summarized and discussed by Reynard & *alii* (2009).

Criteria proposed in this paper for the evaluation of geomorphosites come from a critical examination of other relevant papers (Carton & *alii*, 1994; Rivas & *alii*, 1997; Grandgirard, 1999; Coratza & Giusti, 2003, 2005; Panizza, 2001; Panizza & Piacente, 2003; Pralong, 2005; Bruschi & Cendrero, 2005; APAT, 2007; Reynard & *alii*, 2007; Pereira & *alii*, 2008).

The three main categories of values to be assessed are referred to as scientific value, additional values and potential for use, and the parameters for their definition are still being debated by different authors.

TABLE 3 - Formula implemented into the database in order to calculate values for both geomorphosites and itineraries. Some calculated values (i.e. SV, GV, Puss, PPU, AFc, AFs, Puc, Pus, EIn) can never obtain minimum values equal to zero because some parameters (i.e. geodiversity, temporal and spatial accessibility) are set never equal to zero. The abbreviation used in the formulas are indicated in table 2 for what concerns Scientific and Additional values. Iu = Index of Use; Puss = Potential for use sensu strictu. PPU = Partial potential for use. TA = Temporal accessibility; Vi = Visibility; Se = Services; NT = Number of tourists; SA = Sport activities; = LC = Legal constraints; UGI = Use of geomorphological interest; UAI = use of additional values; SGs = Presence of geomorphosites in the surroundings. CA = Calculated accessibility; Ti = Typology; St = Steepness; Sl = Sloping; Wi = Width; GM = Ground material; WSP = water/Snow along the path; SI = Slope inclination; SM = Slope material; DC = Degree of conservation of the path; HI = Human interventions; TI = Tourist Information. AFc = Accessibility factor complex; AFs = Accessibility factor simple; PUc = Potential for use complex; Pus = Potential for use simple. SIn = Scientific Index; EIn = Educational Index

CALCULATED VALUES	EQUATION	RANGE
(1) Scientific Value	SV = (GM + PgM + EE + SE + Gd + GI + EI + OI + In + Ra)	0,5-10
(2) Additional Value	AV = (C + Ae + SE)	0-3
(3) Global Value	GV = (SV + AV)	0,5-13
(4) Index of use	IU = EE + SE + Ae	0-3
(5) Potential for use *sensu strictu*	PUss = (TA + Vi + Se + NT + SA + LC + UGI + UAI + SGs)	0,25-9
(6) Partial potential for use	PPU = (PUss + IU)	0,25-12
(7) Calculated Accessibility	CA = (Ti + St + Sl + Wi + GM + WSP + SI + SM + DC+ HI + TI)	0-11
(8) A_Factor_c	AFc = ((CA/11)+(SAc/0.4))/2; SAc ≤ 0.4	0,25-1
(9) A_Factor_s	AFs = (1+(SAc/1))/2; SAc ≥ 0.6	0,8-1
(10) Potential for use	PUc = PPU + AFc	0,5-13
(for on-foot itineraries, excluding main roads)	PUs = PPU + AFs	1,05-13
(11) Potential for use		
(12) Scientific Index	SIn= (GM + PgM + GI + OI)/4	0-1
(13) Educational Index	EIn= [EE + Ae + (A_Factor_c/s)]/3	0,083-1
(13) ITINERARY	Σ SCIENTIFICs / (n° sites*MAX)	0-1
	Σ ADDITIONALs / (n° sites*MAX)	0-1
	Σ GLOBALs / (n° sites*MAX)	0-1
	Σ POTENTIAL FOR USEs / (n° sites*MAX)	0-1
	Σ SCIENTIFIC INDEX / (n° sites)	0-1
	Σ EDUCATIONAL INDEX / (n° sites)	0-1

In table 2 the scientific and additional values adopted in the database and that concur to define the global value of the site are indicated, as well as the main bibliographic references and considerations. The numerical parameters of each evaluation criterion are illustrated in more detail in Bollati (2012). Here we do not discuss the attribute values of geomorphosites but their role in the proposed geomorphosite evaluation method and its application for educational purposes. When starting the geomorphosite evaluation procedure, it is important to clarify the main aim of the assessment (scientific research, educational projects, valuation and promotion…) (Reynard & *alii*, 2007) as well as the scale of the investigation (local, regional, national), which influences some scientific value parameters like rareness and geodiversity (*sensu* Eberhard, 1997).

A particular mention is due to the geomorphosite parameter educational exemplarity, which is a debated attribute in literature; most authors consider it to be among the scientific/central values of a site of geomorphological interest (Coratza & Giusti, 2005; Pereira & *alii*, 2008; Reynard & *alii*, 2007; Pelfini & *alii*, 2010) rather than among the additional values (e.g., Serrano Cañadas & Gonzalez Trueba, 2005). This attribute is particularly meaningful in the case of active geomorphosites (Reynard, 2004) where students can easily observe the rapid changes in the landscape in response to geomorphological and geological processes (Reynard & *alii*, 2007; Bollati & Pelfini, 2010).

In this sense, the geomorphological setting of a region reflects its geological background (see geological landscape *sensu* Gisotti, 1993): the sites most representative of the Earth surface modelling are strictly related to the underlying geological setting. Hence, the geological features of the landscape are considered in terms of two aspects of the scientific value of the proposed methodology:

– their relation to the visible landscapes that enhances the importance and concurrence of geological elements in the shaping of the actual geomorphological context (i.e. other geological interests correlated to the site, e.g., the presence of tectonic structure and different kinds of rocks);
– their importance in the development of the Earth sciences (geo-historical importance and other geological interests not necessarily related to the site, e.g., for the study area, the presence of meaningful turbiditic facies exemplar of a specific sedimentary environment).

According to Grandgirard (1999), geodiversity (see definition of Eberhard, 1997) is one of the indicators characterizing a geomorphosite and it is also important for educational purposes. Some authors include geodiversity among the scientific qualities of a site (Cendrero & Panizza, 1999; Rivas & *alii*, 1997; Pereira & *alii*, 2008). According to others (e.g., Zouros, 2007) it is worth evaluating on its own, as an additional value. The concept of geodiversity is strictly linked to the dimensions of the area as well as the rareness, and it may be assessed in different ways depending on the scale of analysis (Panizza & Piacente, 2009). Moreover, Panizza & Piacente (2009) underlined how geodiversity of a landscape can be considered with respect to other landscapes (extrinsic) or with respect to the same landscape, for example, related to past and different climatic conditions (intrinsic).

Another relevant parameter is the ecologic support role of geomorphosites, which is sometimes underestimated but could be meaningful in geomorphosite evaluation in critical areas and also for multidisciplinary approaches. It is useful in the case of glacial environments where the retreat of glaciers is followed by the enlargement of proglacial areas, with the generation of new geomorphosites (increase of geodiversity) (Diolaiuti & Smiraglia, 2010), and by the increase of the supraglacial debris coverage (e.g., Miage Glacier; Pelfini & *alii*, 2005). In more detail, the role of vegetation in proglacial areas for studying ecesis (McCarthy & Luckman, 1993) or in a supraglacial environment for investigating present and recent glacial dynamics (Pelfini & *alii*, 2007) becomes a critical factor that leads to an increase of the scientific value of a geomorphosite (Garavaglia & *alii*, 2010).

The parameters for calculating the potential for use (table 2) have been adapted mainly from Pereira & *alii* (2008) and Bruschi & Cendrero (2005). Regarding the exploitation of geomorphosites for tourism, Pralong (2005) provided an accurate analysis and adaptation of all the scientific attributes and additional values for this scope, and it has been considered in the structuring of this section.

Two of the parameters adopted for the assessment of the scientific value (educational exemplarity and spatial extension) (Bruschi & Cendrero, 2005; Pralong, 2005) and one of the additional values (aesthetic value) (Pralong, 2005) have also been considered in order to calculate the potential for use; the Index of Use, deriving from their sum, is introduced in table 3.

The spatial extension result is important because it gives an indication of whether the site is a spatially limited site or an entire geomorphological landscape (*sensu* Reynard & *alii*, 2009), which is favoured by the general public. It can have also implications for both geodiversity assessment and tourism strategies (Pereira & Pereira, 2010; Rodrigues & Fonseca, 2010). Pereira & Pereira (2010) adopt the spatial extension criterion in selecting potential geomorphosites to be evaluated in the following phase of numerical assessment. Moreover, Rodrigues & Fonseca (2010) underline that it is possible to create appropriate evaluation methodologies based on the spatial extension of the sites.

The socio-economic additional value may influence the potential for use of a site if the site is inserted in a tourist area or circuit; in this sense, detailed categories have been created ad hoc in the potential for use (services, number of tourists, sport activities, legal constraints).

A section dedicated to the evaluation of accessibility for on-foot itineraries has been developed, adapting parameters proposed by Bozzoni & Pelfini (2007) (parameters in table 1). Rodrigues & Fonseca (2010) combined the accessibility parameters with the physical properties of the sites (e.g., degree of consolidation in the special case of glacial deposits) in order to establish the degree of vulnerability for subsequent management considerations.

The creation of two specific indexes finally provides indications on the strictly scientific and educational value with the aim of focusing on one or on the other for future applications: scientific index (model of geomorphological evolution, model of palaeogeomorphological evolution, geo-historical importance, other geological interests; formula 8 in table 3) and educational index (educational ex-

TABLE 4 - Scores of the 13 sites that have been evaluated along the Trebbia River. The sites are ranked by global value and the bold values correspond to the sites that obtained values above the average. The sites that have been selected for the educational itinerary are underlined

Geomorphosite	SCIENTIFIC VALUE	ADDITIONAL VALUES	GLOBAL VALUE	POTENTIAL FOR USE	EDUCATIONAL INDEX	SCIENTIFIC INDEX
<u>San Salvatore entrenched meanders</u>	**7.25**	**2.67**	**9.92**	**10.6**	**0.95**	**0.75**
Pietra Parcellara ophiolite crag	**7.25**	**2**	**9.25**	**10.25**	**0.94**	**0.58**
Brugnello	**7**	**2**	**9**	**10.35**	**0.93**	**0.75**
<u>Barberino gorge</u>	**7.59**	1.17	**8.76**	**9.5**	**0.83**	**0.66**
Caverzago ancient surface	5.83	**2.67**	**8.5**	**10.05**	**1**	**0.58**
<u>Bobbio plain</u>	**6.34**	**2**	**8.34**	**9.47**	0.55	0.66
<u>Rivalta terrace</u>	5.17	**2**	7.17	**9.35**	**0.66**	0.25
Travo	5.34	**1.67**	7.01	8.52	0.55	0.37
Marsaglia alluvial fan	6,25	0.67	6.92	8.85	**0.66**	**0.62**
Rivergaro	5.59	0.67	6.26	8.62	0.49	0.54
Statto palaeo-landslide	5.17	1	6.17	8.02	0.55	0.5
Casaliggio braided reach	5.76	0.33	6.09	7.21	0.56	0.33
Donceto landslide	4.92	0.67	5.59	7.66	0.45	0.5
MAXIMUM OBTAINABLE	**10**	**3**	**13**	**13**	**1**	**1**
MAXIMUM OBTAINED	**7.59**	**2.67**	**9.92**	**10.6**	**1**	**0.75**
MINIMUM OBTAINED	**4.92**	**0.33**	**5.59**	**7.21**	**0.45**	**0.25**
MEAN	**6.04**	**1.50**	**7.66**	**9.11**	**0.70**	**0.55**

emplarity, aesthetic value, accessibility factors; formula 9 in table 3).

The application is focused especially on tourist areas (Panizza, 1999; Brandolini & *alii*, 2007; Pelfini & *alii*, 2009) and on active geomorphosites that have been demonstrated to be very useful for educational purposes (Bollati & Pelfini, 2010). Particularly meaningful in this framework, a section is dedicated to hazard evaluation (e.g. river floods, gravity processes, debris flows, etc.), vulnerability, impact description (table 1) and to the qualitative assessment of risk/impact scenarios (*sensu* Bell, 1998). This section represents an additional alternative to the other interesting methodologies for assessing risk/impact scenarios already proposed (Rivas & *alii*, 1997; Panizza, 1999; Serrano Cañadas, 2002; Serrano Cañadas & Gonzalez Trueba, 2005; Bruschi & Cendrero, 2005; Pralong, 2005; Rodrigues & Fonseca, 2010).

Hazardous processes can represent not only a hazard for tourism or human infrastructure in the area (Panizza, 1999; Piccazzo & *alii*, 2007) but also a danger for the site itself (fragility of the site, Serrano Cañadas, 2002), because they can threaten its survival in moments of sudden intensification of the processes (Bollati & Pelfini, 2010) as mentioned above (table 1: threat to geomorphosite survival). In more detail, the section on vulnerability focuses on the human factors, considering especially those that can trigger the normal degree of vulnerability (mileage difficulties, knowledge of the environment and meteorological conditions).

Finally, the impact of an activity on the site (vulnerability of the site, Serrano Cañadas, 2002) has been considered in two ways according to Coratza & Giusti (2003): the impact on the scientific value and the impact on the aesthetic value.

The information stored in this section gives indications for comparing fragile geomorphosites of high scientific value, which are suitable for protection, with those that are not so fragile and suitable for divulgation and promotion, providing further information for the best usage of the sites.

All this information may be described more broadly in both sections of general information, geomorphological description and deepening and description, with the possibility of linking references and documents (table 1).

RESULTS FROM APPLICATION TO TREBBIA VALLEY FOR EDUCATIONAL PURPOSES

The importance of rivers as geomorphosites has been highlighted in terms of the landscapes produced by fluvial processes (Leopold, 1969) and more recently with an approach for site selection based on geometric criteria and spatial analysis (Wiederkehr & *alii*, 2010). Wiederkehr & *alii* (2010) analyse the problem of selecting fluvial reaches of high environmental value in a river basin and propose a combination of methodologies, including geographical information system (GIS) and digital elevation model (DEM) analysis and identification of fluvial patterns using ortophotos coupled with vector layers.

The use of the database for educational purposes is tested on a fluvial valley (Trebbia Valley portion in Emilia Romagna, Italy; fig. 2,a), an area characterized by active geomorphosites where geotourism itineraries have already been developed (Regione Emilia Romagna, 2002; 2009). Thirteen sites along the river have been selected and evaluated (fig. 3).

The valley is characterized by four main sites of community importance (SCIs) defined on the basis of the Eu-

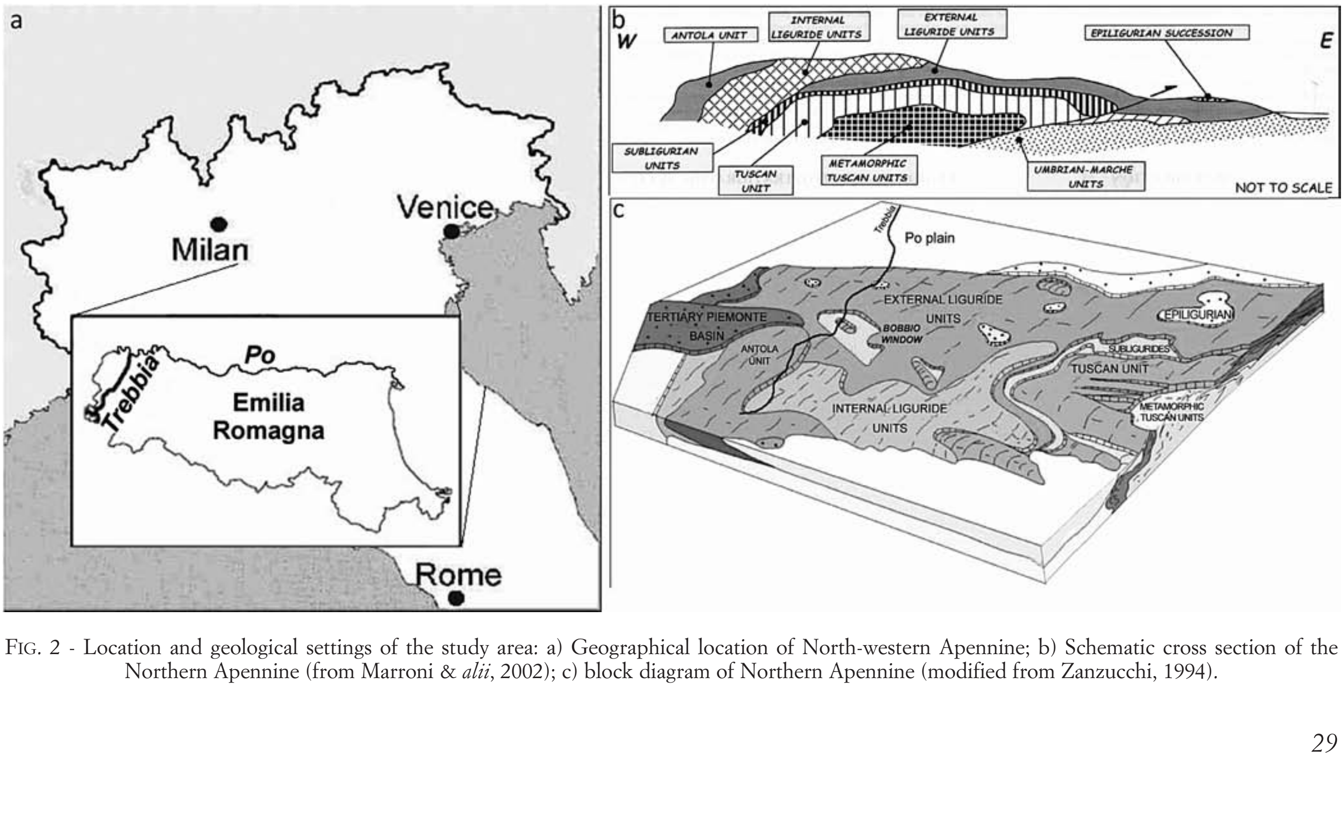


FIG. 2 - Location and geological settings of the study area: a) Geographical location of North-western Apennine; b) Schematic cross section of the Northern Apennine (from Marroni & *alii*, 2002); c) block diagram of Northern Apennine (modified from Zanzucchi, 1994).

ropean Commission Habitats Directive (92/43/EEC): San Salvatore entrenched meanders (SIC IT4010006), Trebbia River between Bobbio and Perino (SIC IT4010011), Pietra Parcellara ophiolite crag (SIC IT4010005), and lower reach of Trebbia River (SIC IT4010016). The last one is also subject to special protection zone (ZPS) rules but without any restriction on usage. In the lower reach, from Piacenza as far as the Bobbio area (sites 4-13; fig. 3), the Regional Fluvial Park is a recent institution (2009).

The labelling of some sites as SIC (Site of Communitarian Interest) does not in any way influence the use of the sites as no restrictions are applied, and from the filling in of the form of risk/impact scenario, no fragile sites (impact evaluation section) have been individuated along the valley.

The numerical results of sites are reported in table 4, where the geomorphosites evaluated along Trebbia Valley are reported and ordered by global value.

The geomorphological peculiarities of the mountain part of Trebbia Valley are closely linked to structural and lithological control on landforms, providing different geological landscapes (Bartolini & Peccirillo, 2002; Gisotti, 1993; Regione Emilia Romagna, 2009). The river has acted on different lithotypes, leading to the formation of a sequence of peculiar fluvial valley morphologies (model of geomorphological evolution) especially suitable for educational, and more generally for tourist, itineraries (educational exemplarity) (Regione Emilia Romagna, 2002, 2009). In fact, there are extraordinary entrenched meanders carved in San Salvatore Sandstone and Brugnello Shale.

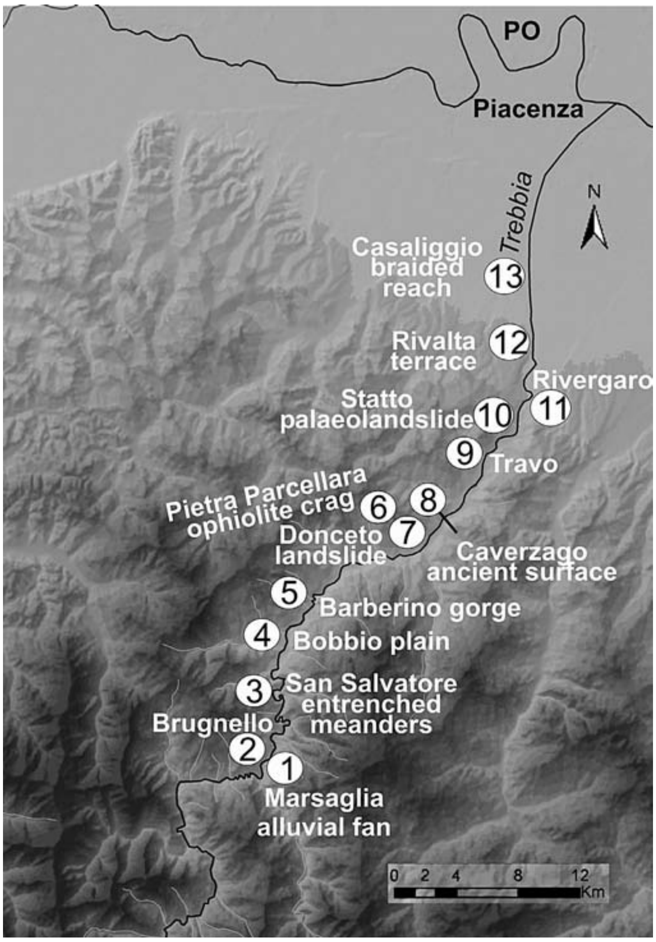


FIG. 3 - DEM of Trebbia Valley showing the investigated fluvial reach from Marsaglia to the Po confluence (Piacenza, Emilia Romagna). The location of the geomorphosites analyzed along the river is indicated.

Here, more so than elsewhere, it is possible to individuate different structural units of the Northern Apennine orogen (Valloni & *alii*, 1991; Zanzucchi, 1994; Servizio Geologico d'Italia, 1997; fig. 2,b,c). In particular, in the middle-upper (southern) portion of the river basin (sites 1, 2, 3, 4; fig. 3), there is a fundamental structure for understanding the Apennine structure: the Bobbio tectonic window (Zanzucchi, 1994). In the 1930s, the Bobbio tectonic window was first recognized within the Argan's new theories on folded mountains (Servizio Geologico d'Italia, 1997). In addition, in this area of corresponding outcrops of Formazione di Bobbio (San Salvatore Sandstone and Brugnello Shale; Oligocene-Early Miocene), the turbiditic sequences of Apennine domain were well described. These formations are part of the Tuscan Unit, the youngest and deepest unit of the structure, which outcrops as a result of heavy erosion of Trebbia related to recent uplift.

These features confer on these sites a high value for the geo-historical importance and other geologic interests attributes, which reach the maximum (1) because they are correlated with the geomorphology.

The possibility at San Salvatore village, placed on a meander spur that is undercut by the river channel, to get down to the meandering river point bar by an easy walking path (accessibility) provides a good occasion for understanding the erosion-transport-deposition processes of the river.

Another salient geological feature is represented by several olistolites of ophiolites emerging in the landscapes carved in clayey terrain (APAT, 2005). The outcrops of ophiolite crags like Pietra Parcellara (site 6), on which in addition a peculiar vegetation grows (ecologic support role) (Vercesi, 2005), are representative of the morphoselection process acting on the more resistant ophiolites with respect to the surrounding clay, which is eroded more quickly and easily. In the same ophiolitic olistolite context, the Barberino gorge (site 5; fig. 3) shows, in addition to morphoselection, the interaction of river activity with the ophiolite bedrock giving the possibility of illustrating the local base level concept and a superimposed or antecedent stream (model of geomorphological evolution; maximum scientific value obtained: 7,59/10; table 4).

In terms of cultural value, the Trebbia Valley constitutes a natural passage between Liguria and the Po plain, and this fact explains the dense population throughout the different historical ages (Marchetti & Dall'Aglio, 1982; Bernabò Brea & Maffi, 1999). The highest-valued sites among those evaluated are San Salvatore entrenched meanders (site 3), Bobbio plain (site 4), Travo (site 9; fig. 3), and Rivalta terrace (site 12; fig. 3).

In the San Salvatore area, the old depositional terraces host the remnants of Roman mansions (maximum additional value obtained: 2,67/3; table 3) (Marchetti & Dall'Aglio, 1990).

The strict relationship between landscape evolution and human settlements is evident at Bobbio village, where the Ponte Gobbo testifies to the variation of bankfull position and width resulting from several structural modifications over time.

Since the 1970's, researchers at Travo have been focusing on the Neolithic age, when the fluvial terraces on which the village is settled experienced an increase in population settlement because of the suitable conditions for agricultural exploitation (Bernabò Brea & Maffi, 1999). The Sant'Andrea village on the fluvial terrace of Travo is the most important and the widest one among the several settlements on the fluvial terraces of the valley.

Rivalta village is located on the edge of a river terrace on the plain, and the toponym (ripa alta) is indicative of the will to find a protected place with respect to the hazardous fluvial processes (floods) but at the same time without being far from water availability.

The existence of folk tales featuring both Bobbio (San Colombano, the Devil and the Gobbo Bridge; Tosi, 1978; Boccaccia & *alii*, 2000) and the inhabitants of Rivalta Castle may arouse interest in investigating the real origin of the place.

There are a number of considerations regarding the overall numerical results. First of all, the medium-high value of all the sites along the valley (mean global value 7,66/13; mean potential for use 9,11 /13; table 3) is evident.

In figure 4 the results obtained through the database evaluation are spatially represented through GIS. The trends of the values along the valley are illustrated and shown to be quite concordant. The importance of the sites, especially in the upper (sites 1-5; fig. 3) but also in the middle (sites 6-9; fig. 3) portion of the valley, may be linked with the more evident relief and landforms that are more manifest and diversified.

In more detail, the maximum values of both global value and potential for use are attained by the sites near the Bobbio tectonic window, suggesting that important underlying geological features may influence the presence of meaningful sites from a different point of view (geomorphological, ecological, cultural, etc.).

The lower part of the valley (e.g., sites 10, 11; fig. 3) attains high values for the scientific index because of the importance of the area for academic research into the processes of channel adjustment as a model for braided-type rivers (e.g., Pellegrini & *alii*, 2008; Duci, 2011).

It is notable that sites that are interesting from a scientific point of view may not always attain high values for educational or dissemination purposes because of the difficulties of the scientific concepts they represent, the lack of recreational activities in the same areas necessary for scholars, or low additional values like aesthetic and cultural ones.

In fact, greater diversification among sites has been obtained through the use of the educational index (fig. 4,d) that highlights some sites as very meaningful for educational purposes. In relation to the educational aim of this research, the excluded sites, even if very representative and spatially extended, are characterized by the difficulty of the topic and of recognising the landforms for non-expert students (e.g., Donceto landslide, site 7, fig. 3, and Statto palaeo-landslide, site 10, fig. 3).

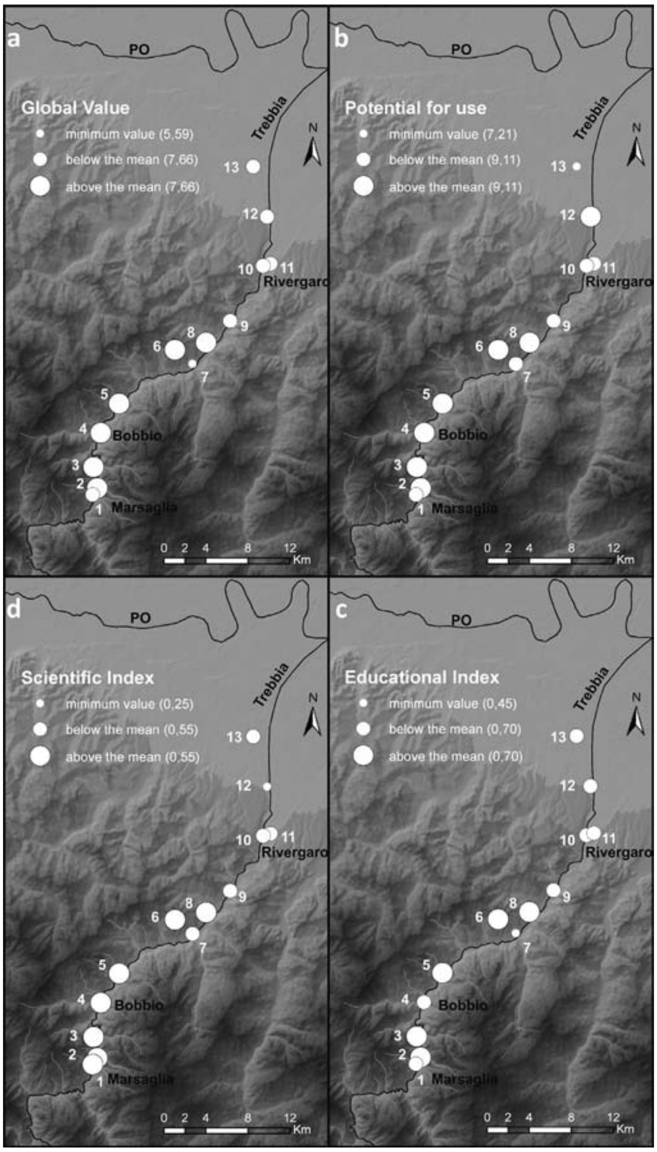


FIG. 4 - Distribution of assessed geomorphosites along the Trebbia River symbolized on the base of the numerical evaluations: a) global value; b) potential for use; c) scientific index; d) educational index.

USE OF THE DATABASE FOR SELECTING SITES IN TREBBIA VALLEY FOR CREATING AN EDUCATIONAL ITINERARY

With the aim of creating an educational itinerary along a complex geomorphosite like a river valley, it is fundamental to focus attention on i) educational objectives, ii) target audience, and iii) time available for the fieldwork.

The proposed itinerary has been realized for the first level of secondary school, and the selected topics in the Trebbia Valley framework are:

– fluvial processes and shaping;
– changes in the landscape morphology in relation to outcropping rocks;
– analysis of the interaction of human settlements and vegetation elements with geological and geomorphological processes.

For the first two aims, we need to select sites that combine good/excellent representativeness of a morphogenetic system and geologic interests correlated with geomorphological ones together with the highest value of educational exemplarity. For the last aim, high cultural value sites are fundamental. The potential for use is once again considered an important indicator for the selection.

In more detail, the selected sites for the itinerary (underlined in table 4) are:

– San Salvatore entrenched meanders (site 3; fig. 3): exemplar representativeness of a morphogenetic system (entrenched meanders and morphoselection; 1/1), geologic interests correlated with geomorphological ones (Bobbio Tectonic window; 1/1), presence of cultural assets /customs correlated with geomorphological features (romans remnants on the terraces 1/1); good accessibility (7,9 / 11), potential for use above the mean (10,6/13);
– Bobbio plain (site 4; fig. 3): presence of cultural assets / customs correlated with geomorphological features (the modification of the landscape in the particular case of the river course; cultural value 1/1), potential for use above the mean (9,47/13);
– Barberino gorge (site 5; fig. 3): exemplar representativeness of a morphogenetic system (gorge formation and ophiolites role in morphoselection, 1/1), ecological support role (serpentinofite vegetation, 0,67/1), potential for use above the mean (9,5/13). Instead of the ophiolitic crag of Pietra Parcellara, which obtains a higher global value, the Barberino gorge has been chosen to highlight the lithologies-river relation;
– Rivalta terrace (site 12): presence of cultural assets /customs correlated with geomorphological features and related toponym illustration (cultural value 1/1), scientific results of dendrochronology analysis regarding braided river modifications over time at disposal for popularization (ecological support role 0,67/1; presentation of a scientific method for investigating geomorphologic topics), potential for use above the mean (9,35/13). With respect to other sites in the lower portion of the river (e.g. Rivergaro, site 11, and Casaliggio, site 13), it has obtained a higher global value and presents additional elements to enrich the educational applications.

The structure of the educational project and the results obtained with students of a first level of secondary school are described in Bollati & *alii* (2011).

DISCUSSION AND CONCLUSIONS

In the present paper, the selection methodology for sites of interest for educational purposes is intended for geomorphosites in the wider framework of geosites. This

FIG. 5 - Photos of the geomorphosites selected for the educational itinerary. The itinerary has been developed along the main road system close to the fluvial reach. Site 3, San Salvatore entrenched meanders, photo by G. Duci; site 4, Bobbio plain and village, photo by I. Bollati, and site 5, Barberino Gorge, photo by A. Bazzi; site 12, Rivalta Castle, photo by L. Pellegrini.

choice is based on the necessity of examining sites on the basis of features that can be compared, even including in the evaluation procedure the strictly geological features of the area (i.e. geohistorical importance, and the other geologic interests part of the scientific value).

The geomorphosite database application proposed herein has been realized after a detailed analysis of all the literature and after testing the method in the field with other geomorphological researchers. The results obtained from applying the selection methodology in Trebbia Valley demonstrate its usefulness in ranking sites and individuating the areas of maximum interest in a region. They also highlight the differences that can emerge among these sites through the database evaluation procedure.

Unlike other relational-geographical databases that are built to collect a great amount of information to be selected by the general public (e.g., Ghiraldi & *alii*, 2009; Diolaiuti & *alii*, 2001), the described methodology has been designed for researchers to store and elaborate data related to geomorphosites.

It is shown to be useful during the site-selection phase for specific goals like, in this case, educational applications, but also for tourism promotion and scientific research. The elaboration of evaluation results with the help of GIS allows a spatial characterization of the Trebbia Valley in terms of the geoheritage to individuate the areas that are more suitable for educational applications (educational index).

The effort of popularizing an extremely scientific language (Piacente, 1999; Pelfini & *alii*, 2010) and the strategies to simplify complicated topics for different levels of audience represent a further step and, intrinsically, a further challenge once the sites have been selected as the most exemplary from an educational point of view for reconstructing the landscape evolution.

The selection of sites for an educational itinerary has to take into account the topics to be covered during the fieldwork; in this case we chose sites with high representativeness of morphogenetic systems and high cultural value when human settlements are particularly linked with the geomorphological setting and the ecological support role of the outcropping lithologies.

Based on all these considerations, the database is a good tool to:

– store a great quantity of data for different areas located in different geomorphological contexts and make rational comparisons among them;
– provide both a global and local view of the area by sorting geomorphosites on the basis of global value and single features (educational exemplarity, accessibility, or combinations of parameters) thanks to the compatibility with GIS;
– establish the best geomorphosites in relation to the aims of a project, considering potential for use and global value.

This paper is mainly focused on the educational application of the database, but the methodology may be applied for different purposes. In fact the database may help academic researchers, and also tourism promotion and management personnel, in the evaluation and analysis of a region's geoheritage, assessing also wide territories. This allows discrimination between the most important geomorphological emergencies of an area, and the numerical, and therefore more comparable, scores are indicative also of the meaning of the sites as geomorphosites with respect to those of other morphogenetic and morphoclimatic contexts.

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